

## Title of the Invention

### OXYGEN ABSORBER

#### Background of the Invention and Related Technical Field

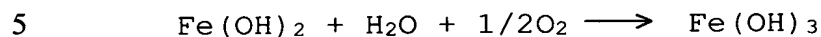
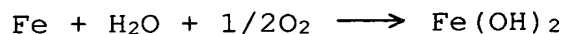
5       The present invention relates to an oxygen absorber. More particularly, the present invention relates to a composition of an oxygen absorber with improved oxygen absorption performance.

      An oxygen absorber is a material capable of absorbing oxygen from surrounding atmosphere. Conventionally, the oxygen  
10 absorber has been used for protecting packaged foods and other products against spoilage, mold growth, color change, rancidity, loss of a nutritive value, insect damage and loss of quality. The oxygen absorber has been also used for protecting a metal product against corrosion, an antique wood against deterioration,  
15 a chemical and drug against oxidation, and so on.

      The oxygen absorber has been produced in a variety of forms such as a packet form, powder, a pellet, a sheet and a tablet according to applications thereof. When the oxygen absorber is retained in a sealed packaging of food, the oxygen absorber  
20 absorbs oxygen inside the sealed packaging and maintains the oxygen content at a low level.

      In the food storage industry, the use of the oxygen absorber has been critical for increasing a storage life of foods for a long-term storage. There have been two types of  
25 oxygen absorbers used for the storage of food. The first type requires moisture from surrounding atmosphere or food to perform the absorption. The second type contains moisture and is suitable for dry pack canning with low moisture. The first type works slower as the oxygen absorber must first absorb moisture  
30 before absorbing any oxygen. Because the second type contains moisture, the oxygen absorber starts absorbing oxygen immediately and tends to last a shorter period of time as compared with the first type. These characteristics are selected according to the applications.

The oxygen absorber performs the oxygen absorbing action through a chemical reaction as follows:



A typical conventional oxygen absorber contains iron powder, and the iron powder reacts with oxygen in the surrounding atmosphere, thereby causing the iron powder to rust.  
10 When a surface of the iron powder has oxidized, the absorbing action stops. Therefore, it is necessary to use fine iron powder with a large surface area to absorb a large quantity of oxygen.

In order to promote the reaction of the iron, it is  
15 sometimes tried to add an electrolyte such as sodium chloride or other alkaline or alkaline earth metal chloride. Also, to provide water necessary for the reaction, it has been tried to add a component such as activated carbon and silica gel for releasing water.

20 U.S. Patent No. 5,721,187 has disclosed an oxygen absorber comprising an active carbon material layer and an oxygen absorbing layer comprising 15 to 80% by weight of a thermoplastic resin and 85 to 20% by weight of an oxygen absorbing agent. An amount of the active carbon material is 0.2  
25 to 15% by weight relative to the oxygen absorbing agent. The oxygen absorber is easy to handle and excellent in oxygen absorbing performance. However, a rate of absorbing oxygen has been found not fast enough for a certain application

U.S. Patent No. 6,586,514 has disclosed a composition  
30 comprising an oxidizable metal component, an electrolyte component and a non-electrolytic acidifying component. When the composition is blended with a flexible polymeric resin, it is possible to obtain good oxygen-absorbing performance with improved oxidation efficiency as compared with a rigid

thermoplastic resin. The non-electrolytic acidifying component needs to be thermally stable under a condition of melt compounding with the polymeric resin, particularly for an extrusion coating application. Further, the efficiency of absorbing oxygen has not been high enough. Also, the composition includes three different components, resulting in complex material handling and manufacturing process.

#### Summary of the Invention

In view of the problems described above, the present invention has been made. The object of the invention is to provide an oxygen absorber having a simple composition with an improved efficiency of absorbing oxygen. The present invention provides an oxygen absorber with a reduced cost and without the complexity in material handling and manufacturing process.

In order to achieve the objects described above, according to the present invention, an oxygen absorber includes an iron powder, and a first layer of iron chloride coated on a surface of the iron powder. Further, an oxygen absorber according to the invention includes a matrix material filled with the iron powder covered with iron chloride through a chemical reaction or other methods.

In the invention, the oxygen absorber is the matrix material filled with the iron powder coated with the iron chloride. Accordingly, the oxygen absorber comprises two major component, thereby eliminating the complex material handling and manufacturing process. The iron powder is coated with the iron chloride through a reaction between iron and hydrochloric acid. Alternatively, anhydrous ferric chloride is dissolved in ether or alcohol to obtain a coating solution, and the iron powder is added in the solution to coat the surface thereof with ferric chloride. It is also possible to mix the iron powder with solid anhydrous ferric chloride in an intensive mixer so that a

chemical reaction between the iron and the ferric chloride takes place on the surface of the iron powder to form the first layer.

According to the present invention, the iron powder may have an average diameter of less than 100 micrometers, and may  
5 be sponge iron powder with porous surface. Further, the iron powder may be carbonyl iron powder with an average diameter of less than 20 micrometers.

According to the present invention, the first layer is formed of anhydrous ferric chloride, and is coated on the iron  
10 powder such that a ratio of chloride to iron is 0.1% to 10% by weight. The first layer may have a thickness of less than 100 nanometer.

According to the present invention, the matrix material is a plastic having a melting point of 80°C to 300°C such as  
15 polyethylene, polypropylene, polystyrene, nylon, polyesters, polycarbonate, polyvinylchloride, and the like. The matrix material may be filled with the iron powder at 50% to 90% by weight.

## 20 Detailed Description of Preferred Embodiments

Hereunder, embodiments of the present invention will be explained.

According to the present invention, an oxygen absorber includes an iron powder, and a first layer of iron chloride  
25 coated on a surface of the iron powder through a chemical reaction. Further, an oxygen absorber includes a matrix material filled with the iron powder covered with iron chloride.

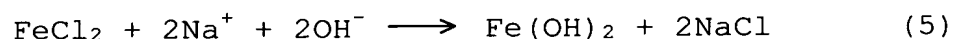
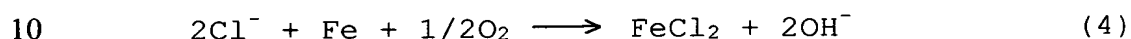
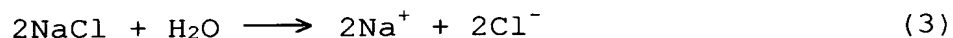
When iron exists with iron chloride, the following reaction will occur.

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In reaction (1),  $\text{Fe}_2\text{Cl}_2$  is a part of iron crystal lattice and unstable, and reaction (2) takes place at a fast rate. As it can be seen, the iron chloride is not consumed through the reactions. Accordingly, a small amount of iron chloride would  
5 be enough for the reactions.

In the conventional system, sodium chloride has been used to supply electrolyte as follows.

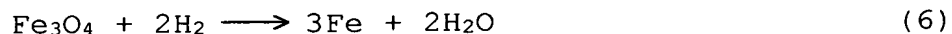


As compared with reaction (2), reaction (4) progresses at a very slow rate, resulting in undesirable efficiency of absorbing  
15 oxygen. Further, commercial iron powders are covered with oxide, therefore it takes a relatively long period of time for acid to penetrate into the oxide layer. According to the present invention, it is possible to facilitate the process of penetrating into the iron crystal lattice.

20 In the embodiment of the present invention, it is preferred to use fine sponge iron powder with relatively large surface area. The fine sponge iron powder can be made through hydrogen reduction of powder iron oxide in solid state. The powder is then classified by size, since finer powder is more suitable for  
25 the application. The iron oxide is obtained as a byproduct in a steel manufacturing process by scalping a steel ingot. The obtained iron oxide is then dried and ground to fine iron oxide powder. The fine iron oxide powder is heated to remove any moisture before being transferred to the next step.

30 As an example of a process of manufacturing the fine iron powder, an iron oxide byproduct in a steel mill as a result of scalping steel ingot is dried and grind to fine iron oxide powder. The iron oxide is then heated to remove any moisture. In a special continuous belt oven, the iron oxide is heated

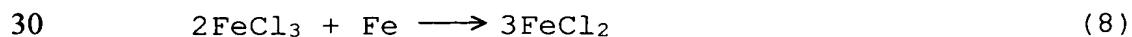
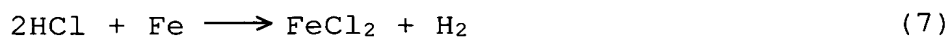
while hydrogen is introduced. An exothermic chemical reaction takes place according to the following equation:



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The formed iron is spongy and the particles have a relatively large surface area as compared to solid beads. The powder is then classified to different mesh sizes by passing the iron powder through a series of screens. It may be preferred to  
10 use the finest iron powder of 325 mesh (about 50 micrometers in diameter). In general, the finer the powder is, the larger the surface area becomes, resulting in a higher rate of the reaction. For some specific application, it is possible to use micronized iron powder (about 10 micrometers in diameter) or carbonyl iron  
15 (about 3-5 micrometers in diameter) provided that cost is not an issue.

The fine iron powder is then coated with iron chloride with one of several methods. The fine iron powder can be reacted with hydrochloric acid to form iron chloride on a surface  
20 according to reaction (7). Alternatively, the iron powder can be coated with anhydrous ferric chloride dissolved in ether or alcohol. Further, the iron powder may be mixed with solid anhydrous ferric chloride in an intensive mixer so that a chemical reaction takes place on the iron powder surface between  
25 the iron and the ferric chloride to form ferrous chloride on the metallic iron powder surface as shown in reaction (8).



Other methods of forming iron chloride on the powder surface includes molten ferric chloride hexahydrate is mixed with iron powder at 100-200 °F, so that ferric chloride  
35 hexahydrate ( $\text{FeCl}_2 \cdot 6\text{H}_2\text{O}$ ) is formed on the surface of the iron powder. It is preferred that the iron chloride layer is formed

through a chemical reaction so that the iron chloride layer becomes a part of the iron crystal lattice. Accordingly, it takes a relatively short period of time for the iron chloride layer to penetrate into the oxide layer on the iron particles to  
5 get the reaction started.

A ratio of the iron chloride to the metallic iron is preferably 0.1 to 10% by weight. The ferrous chloride absorbs moisture from air to form tetra hydrate. In the presence of oxygen, the ferrous chloride tetra hydrate is oxidized to form  
10 ferric chloride. The ferric chloride absorbs moisture from air to form ferric chloride hexahydrate. The ferric chloride hexahydrate is deliquescent and keeps absorbing moisture to become liquid.

It is possible to divide the process of coating the surface  
15 of the iron powder into two separate steps, i.e. the first step of forming the first layer and the second step of forming the second layer. The two-step process may be employed when it is desirable to obtain a thicker and/or more uniform coating. It is possible to perform the first step and the second step using  
20 the same process, or perform the first step and the second step using different steps.

According to the present invention, the iron powder coated with iron chloride can be filled in a matrix material. In the process of producing a material filled with the oxygen absorber  
25 of the present invention, the iron powder coated with iron chloride is fed into an extruder and mixed with a melted polymer at a temperature above a melting point of the polymer. The polymer for this purpose includes polypropylene, polyethylene, polystyrene, polyvinylchloride, and the like. A twin-screw  
30 extruder is preferred to provide good dispersion and smooth surface. During the extrusion, excessive moisture and chloride are removed by applying a vacuum through a venting port.

Other method of forming the iron chloride layer is feeding a polymer and iron powder into a twin-screw extruder and

injecting hydrochloric acid or molten ferric chloride hexahydrate to react directly with the iron powder in the extruder to form iron chloride on the powder surface.

Undesirable reaction by-product is removed from the extruder through a vacuum vent. In that case, it is necessary for the twin-screw extruder to be able to handle hydrochloric acid and molten ferric chloride hexahydrate.

The oxygen absorber formed of the iron powder and the matrix is extruded into strands, and passes through a water bath to obtain pellets.

A concentration of the iron powder coated with iron chloride in the oxygen absorber is normally between 50 and 95% by weight, preferably between 70 to 85% by weight. The oxygen absorber containing 70% iron powder coated with iron chloride will theoretically absorb 200 cc of oxygen per gram. The oxygen absorber can be formed in a disk shape to be filled in a small canister, or a sachet to be placed in a package.

According to the present invention, the oxygen absorber can be mixed with other plastic in a structure of a barrier container for absorbing oxygen in a headspace of the container. In a barrier container combined with a vinyl alcohol, the oxygen absorber of the invention can be added to an adhesive layer adjacent to a layer formed of the vinyl alcohol, or in a layer between a food contact layer and the adhesive layer. Because of the high oxygen absorbing capacity of the oxygen absorber, a container can be formed of a three-layer structure using two extruders to store a food product without a need for a complex co-extrusion setup to use a barrier material.

#### Example 1

Hydrogen reduced iron powder with 325 mesh size and anhydrous ferric chloride were mixed in a Henshel mixer at a 98/2 weight ratio for four minutes. The resultant iron powder coated with iron chloride was mixed with polypropylene copolymer



SB786 from Basel Corp. at a weight ratio of 72/28, and the mixture was fed into a twin-screw extruder.

The mixture was extruded at a barrel temperature of 400 °F and pelletized into pellets as oxygen absorber.

5        10 g and 0.1 g of the oxygen absorber were placed in a one-liter empty jar containing 21% of oxygen, or 210 cc of oxygen. The oxygen content in the jar was measured after one, three and five days to evaluate the oxygen absorption performance as an amount of oxygen (cc) per one gram of the oxygen absorber. The  
10        same test was repeated three times for each 10 g and 0.1 g samples. The result is shown in Table 1.

Table 1

Sample ID	sample weight (g)	Oxygen content (%)				Absorbed Oxygen (cc/g)		
		0 day	1 day	3 days	5 days	1 day	3 days	5 days
A	1.02	20.8	19.2	17.6	16.6	6.9	13.8	18.1
B	1.02	20.8	19.0	17.4	16.3	7.8	14.7	19.4
C	1.02	20.8	19.0	17.4	16.2	7.8	14.7	19.8
D	0.10	20.7	20.4	20.3	20.1	13.2	17.8	26.4
E	0.11	20.7	20.3	20.3	20.1	16.0	16.0	24.0
F	0.10	20.7	20.3	20.3	20.1	17.8	17.8	22.0

## 15    Example 2

The oxygen absorber described above was mixed with polypropylene (PP) and high-density polyethylene (HDPE) at a weight ratio of 10/90, and the mixtures were extruded into films. The same test used for example 1 was performed to evaluate the  
20        oxygen absorption performance of the films as an amount of oxygen (cc) per one gram of the oxygen absorber for up to 35 days. The result is shown in Table 2.

Table 2

Sample	Absorbed Oxygen (cc/g)						
	0 day	1 day	5 days	10 days	15 days	25 days	35 days
PP	0.0	9.2	21.4	28.1	32.4	37.5	42.4
HDPE	0.0	12.2	29.8	32.4	35.0	40.6	43.9

As described above, according to the present invention, it is possible to provide the oxygen absorber with high oxygen absorption performance.

- 5        The invention has been explained with reference to the specific embodiments of the invention. However, the invention is not limited to the embodiments described above, and is limited only by the claims.